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ON THE

STRUCTURE AND USE

OF THE

MALPIGHIAN BODIES OF THE KIDNEY,

WITH OBSERVATIONS ON THE CIRCULATION THROUGH THAT GLAND

BY

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IV. *On the Structure and Use of the Malpighian Bodies of the Kidney, with Observations on the Circulation through that Gland.* *By* W. Bowman, *F.R.S., Assistant Surgeon to the King's College Hospital, and Demonstrator of Anatomy in King's College, London.*

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THESE remarkable bodies have been an object of much interest since their discovery by the great anatomist whose name they bear. Malpighi found they could be injected with great facility from the arteries, and he imagined them to be glands, in which the urine is elaborated from the blood. He seems also to have been of opinion that in them the uriniferous tubes take their rise*. Ruysch examined them with great care, and preserved specimens in his museum in which he believed that he had shown, by injection, that in them the arteries are continuous with the tubes†. This was the principal ground for the famous, but now exploded theory, of the existence of exhalant arteries with open mouths, which in the secreting glands opened directly into the excretory canals. It is probable that this accurate observer mistook the efferent vessel of the Malpighian body for a uriniferous tube, for the efferent vessels of those Malpighian bodies that lie near the medullary part of the kidney, take the same course as the tubes, and are often large enough to be readily mistaken for them. The statement, however, of Ruysch and others‡, that the tubes may be injected from the arteries, is true, though in a different sense from that in which they understood it.

Schumlansky§, some years afterwards, entertained more complete views of the connection between these bodies and the uriniferous tubes, and he has even given an ideal diagram of this connection, which shows that he had a very clear conception of the fact. From a considerable error, however, in the proportion of these bodies to the tubes (represented in his figure), it has been suggested that his description could not have been drawn from nature; a censure that seems to have been little merited.

* See his chapter "de internis glandulis renalibus, earumque continuatione cum vasis," a work not less conspicuous for the sterling accuracy of its observations than for the sagacity displayed in the reasonings based on them.

† "Quarum (gland. Malpigh.) nonnullæ hîc dissolutæ, in ductus Bellinos degenerant."—Ruyschius, Thesaurus Anat. x. No. 86. "Corpuscula rotunda et glandiformia in totum sunt dissoluta et extricata. Ductus qui dicuntur Bellini, in totum quoque repleti sunt propter repletionem arteriolarum."—Ibid. No. 149.

‡ Barnardus Albinus, after injecting the Malpighian bodies from the arteries, "vasa urinæ exinde prodeuntia eodem colore farta beatus conspexit."—Albinus, p. 63, 64. Vide Schumlanskii Dissert. Inaug. Anatomicam de renum structurâ. Argentorati, 1782, p. 69.

§ Schumlansky, *op. cit.*

HUSCHKE* and MÜLLER† are the only modern anatomists who have entered at length into this question, and they both deny that there is any connection between the Malpighian bodies and the uriniferous ducts. The assertions of MÜLLER, in particular, are so positive, and are reiterated in so pointed a manner, that nothing but the most clear demonstration of their erroneous nature would have induced me to uphold an opposite opinion‡.

I was led to the examination of these bodies in the course of an inquiry into the ultimate structure of the true glands, in which I have been engaged for the last two years. I had frequently injected them from the artery, but had never inspected them under high powers of the microscope, until they arrested my attention while examining the structure of the uriniferous tubes. These tubes consist of an external tunic of transparent homogeneous tissue (which I have termed the *basement membrane*), lined by epithelium. The Malpighian bodies I saw to be a rounded mass of minute vessels invested by a cyst or capsule§ of precisely similar appearance to the basement membrane of the tubes. Seeing these similar tissues in such close proximity, it was not easy to resist the conviction that the capsule was the basement membrane of the tubes expanded over the vessels, but, after many trials, I could not at that time succeed in gaining an unequivocal view of their continuity. All that I could accomplish was to perceive here and there an ambiguous approach to such an arrangement, sufficient to make it appear probable.

I should perhaps have relinquished the idea thus presented to my mind, had not accident again drawn me to it. Having, during last summer, been made acquainted, through the kindness of Dr. MILNE EDWARDS, with a new method of injection employed with great success by M. DOYÈRE of Paris‖, I injected some kidneys through the artery, by this method, in order to notice the nature of the vascular ramifications in the Malpighian bodies. I not only found what I sought, but the clearest evi-

* HUSCHKE, Ueber die Textur der Nieren. Isis, 1828, p. 561.

† JOH. MÜLLER, de Glandularum secernentium structurâ penitiori. Lipsiæ, 1830, lib. x.

‡ HUSCHKE says (quoted by MÜLLER), "These corpuscles (Malpighian bodies) are without any connection with the uriniferous ducts. For these most distinctly terminate by free blind extremities, while the Malpighian bodies, everywhere scattered in the interstices of the tortuous uriniferous ducts, are only connected with the blood-vessels."—MÜLLER, *loc. cit.*, p. 87.

MÜLLER says, "Attamen certissimum est, ex vasis sanguiferis, ductus uriniferos planè nunquam usquam repleri, massamque injectam ne quidem laceratione in tubulos uriniferos prorumpere," *op. cit.*, p. 98. "Fines ductuum uriniferorum in corpora Malpighiana desinere, certissimè falsa assertio est," p. 95. "Falsissima est opinio de connexu ullo quopiàm inter corpora Malpighiana sanguifera, et ductuum uriniferorum fines," p. 95. And other passages equally strong might be quoted.

§ First particularly pointed out by MÜLLER, who conceives it to be perfectly closed, except at one point where perforated by the vessels.

‖ This consists of two fluids which mingle in the small vessels, and cause a precipitation there. The best fluids are saturated solutions of bichromate of potass and of acetate of lead. They are injected in succession through the same vessel, whence the method is termed that by *double injection*. KRAUSE published an account of it two years ago, but M. DOYÈRE appears to have arrived at it after a laborious trial of numerous solutions. Both deserve the thanks of anatomists for so valuable an addition to the means of investigation.

dence that the capsule which invests them is, in truth, the basement membrane of the uriniferous tube expanded over the tuft of vessels. The injected material had, in many instances, burst through the tuft, and, being extravasated into the capsule, had passed off along the tube. I have since made numerous injections of the human kidney, and of that of many of the lower animals, and in all, without exception, have met with the same disposition. I have also repeated, with better success than before, the examination of thin slices of the recent organ with high powers of the microscope, and in this manner have fully corroborated the evidence furnished by injections. This mode of examination has likewise led to the interesting discovery of ciliary motion within the orifice of the tube.

According to my own observations, the circulation through the kidney may be stated to be as follows:—All the blood of the renal artery (with the exception of a small quantity distributed to the capsule, surrounding fat, and the coats of the larger vessels) enters the capillary tufts of the Malpighian bodies; thence it passes into the capillary plexus surrounding the uriniferous tubes, and it finally leaves the organ through the branches of the renal vein. Following it in this course, I shall now endeavour to describe the vascular apparatus, and the nature of its connection with the tubes.

With the inconsiderable exceptions just mentioned, the terminal twigs of the artery correspond in number with the Malpighian bodies. Arrived here*, the twig perforates the capsule, and, dilating, suddenly breaks up into two, three, four, or even eight branches, which diverge in all directions like petals from the stalk of a flower, and usually run, in a more or less tortuous manner, subdividing again once or twice as they advance, over the surface of the ball they are about to form. The vessels resulting from these subdivisions are capillary in size, and consist of a simple, homogeneous, and transparent membrane. They dip into its interior at different points, and after further twisting, reunite into a single small vessel, which varies in its size, being generally smaller, but in some situations larger than the terminal twig of the artery. This vessel emerges between two of the primary divisions of the terminal twig of the artery, perforating the capsule close to that vessel, and, like it, adhering to this membrane as it passes through. It then enters the capillary plexus which surrounds the tortuous uriniferous tubes†.

The tuft of vessels, thus formed, is a compact ball, the several parts of which are held together solely by their mutual interlacement, for there is no other tissue ad-

* As the mode of subdivision of this artery in the interior of the organ is well known, I have omitted to describe it. Its branches never anastomose. It almost invariably happens that the twigs ending in the Malpighian bodies are of considerable length, but occasionally (as in fig. 8) two bodies are sessile on very short twigs of a single branch.

† "Cæterùm glomeruli ulterior conformatio in præstantissimis quamvis injectionibus non facilè extricari potest. Videor tamen observasse arteriolam, quæ glomerulo accedit, cirri adinstar dividi, unde tortuosa vascula oriuntur, quæ ansis secum arctè connectuntur et recurrunt. Sed hoc certum est, glomerulos liberè in vesiculis contineri, nec ullibi, nisi uno in puncto, cum vesiculis cohærere."—Müller, *loc. cit.*, p. 101.

mitted into the capsule besides blood-vessels. It is subdivided into as many lobes as there are primary branches of the terminal twig or afferent vessel, and these lobes do not communicate, except at the root of the tuft. There are, therefore, deep clefts between them, which open when the lobes are not greatly distended with injection or blood. The surface of the tuft is everywhere unattached and free, and continuous with the opposed surfaces of the lobes. The whole circumference of every vessel composing the tuft, is also free, and lies loose in the cavity of the capsule. These circumstances cannot be seen in specimens gorged with injection, but only by careful examination of recent specimens with a power of 200 or 300 diameters. The vessels are so perfectly bare, that in no other situation in the body do the capillaries admit of being so satisfactorily studied. It is only where the tuft is large, as in Man and in the Horse, that its lobulated character can be always discerned. When the number of primary subdivisions of the afferent vessel is smaller, the detection of lobes is less easy. They may often be seen, however, in the Frog. In Birds and Reptiles, the afferent vessel seldom divides, but dilates, instead, into a pouch-like cavity, which, after taking two or three coils, contracts again and becomes the efferent vessel. Here of course there are no lobes; but the surface of the whole dilated part is free.

The basement membrane of the uriniferous tube, expanded over the Malpighian tuft to form its capsule, is a simple, homogeneous, and perfectly transparent membrane, in which no structure can be discovered. It is perforated, as before stated, by the afferent and efferent vessels, and is certainly not reflected over them. They are united to it at their point of transit, but in what precise manner I have not been able to determine. Opposite to this point is the orifice of the tube, the cavity of which is continuous with that of the capsule, generally by a constricted neck. I have specimens prepared with the double injection showing this continuity in Mammalia, Birds, Reptiles and Fish; and, in Mammalia and Reptiles, I have obtained the still more satisfactory proof afforded by a clear view of the whole of the textures magnified 300 diameters. As the Malpighian bodies are placed in every possible direction, it often happens that a thin section, parallel to the neck of the tube, cannot at once be obtained: but with perseverance this may always be done. The capsule is then seen to pass off into the basement membrane of the tube, as the body of a Florence flask into its neck. The basement membrane of the tube is lined by a nucleated epithelium of a finely-granular opake aspect, while the neck of the tube and its orifice become abruptly covered with a layer of cells much more transparent, and clothed with vibratile cilia. The epithelium is continued in many cases over the whole inner surface of the capsule; in other instances I have found it impossible to detect the slightest appearance of it over more than a third of the capsule. When fairly within the capsule, the cilia cease, and the epithelium beyond is of excessive delicacy and translucence. Its particles are seldom nucleated, and appear liable to swell by the addition of the water added to the specimen. They frequently fill up the space between the capsule and tuft, and touching the latter, may seem to be united to it.

The lines of their mutual contact may then wear the aspect of a highly delicate areolar tissue, connecting the capsule with the tuft. The cavity existing in the natural state between this epithelium and the tuft, is filled by fluid, in which the vessels are bathed, and which is continually being impelled along the tube by the lashing movement of the cilia. In the Frog, where alone I have as yet been able to see these wonderful organs in motion, they were longer than those from other parts of that animal, and extremely active.

The tubes, on issuing from the Malpighian bodies, invariably become greatly contorted. I have on one occasion seen two of them unite, and from their dichotomous mode of division, when traced up from the pelvis, there can be little doubt that this is constantly their disposition. I have never, in all my examinations, met with any appearance of an inosculation between different tubules. The tortuous tubes unite again and again in twos, and finally, under the name of pyramids of Ferrein, become straight, and converge towards the pelvis, forming the medullary cones or pyramids of Malpighi. The Malpighian bodies are imbedded in a kind of nidus formed among these convolutions, and are touched on all sides by the surrounding tubes. As the emergence of the tube from the Malpighian body can be seen only at one point, it is not wonderful that it should have been overlooked, and that the demonstration should have seemed clear, that the Malpighian bodies merely lie among the tubes, and have no connection with them.

The blood, leaving the Malpighian tufts, is conveyed by their efferent vessels to the great renal reservoir, the capillary plexus surrounding the uriniferous tubes. This, in its general arrangement, resembles that investing the tubes of the testis. The vessels lie in the interstices of the tubes, and everywhere anastomose freely, so that throughout the whole organ they constitute one continuous network, lying on the outside of the tubes, in contact with the basement membrane. This plexus is interposed between the efferent vessels of the Malpighian bodies and the veins.

The efferent vessels of the Malpighian bodies are always solitary and never inosculate with one another: each one is an isolated channel between its Malpighian tuft, and the plexus surrounding the tubes. They are formed by the union of the capillary vessels of the tuft, and emerge from its interior in the manner already explained. After a course of variable length they open into the plexus. Their size is various. In general, they are smaller than the terminal twig of the artery, and scarcely, if at all, larger than the vessels of the plexus into which they discharge themselves. But where the Malpighian tuft is large, the efferent vessel is usually large also, and divides into branches before entering the plexus. This is eminently the case with those situated near the base of the medullary cones, where the medullary and cortical portions of the organ seem to blend. The efferent vessels from these large Malpighian bodies are often three or four times the diameter of those of the plexus, and take a course towards the pelvis of the kidney between the uriniferous tubes. They were formerly mistaken for tubes. They branch again and again in the manner of arteries,

and form the plexus with long meshes which invests this part of the tubes. Some of the veins springing from this plexus form the well-known network on the nipple-shaped extremities of the cones, around the orifices of the tubes, and thence take, with the remainder, a backward course, likewise parallel to the tubes, to empty themselves into venous branches that lie about the bases of the cones. These also, when injected, have been mistaken for tubes.

The other venous radicles are dispersed at about equal distances throughout the cortex of the kidney, and each receives the blood on all sides from the plexus surrounding the convoluted tubes. When these venous radicles are congested, or injected, they mark out the surface of the cortical substance into lobules not very unlike those of the lobules of the liver. On the Horse's kidney, especially, this may be often well seen. Each lobule contains many tortuous ducts with their capillaries, but the convolutions of any one duct are not confined to a single lobule. These radicles unite in an irregularly arborescent figure, anastomose and form the several branches of the renal vein. Those on the surface, especially of the human kidney, have a tendency to converge towards a central vessel which then dips into the interior, and runs, like the rest, towards the hilus. Thus are formed the stellated vessels of anatomists, often conspicuous in diseased specimens. Between the sprawling arms of these stellæ the convoluted tubes, with their plexus, come up to the surface (Plate IV. fig. 11), but the Malpighian bodies are rarely, if ever, visible quite on the surface. They are always covered in by convolutions of the tubes.

The veins from the capsule and surrounding fat join the renal vein in some part of its course. It is probable that the capillaries of the vasa vasorum, within the substance of the organ, pour their blood into the capillary plexus surrounding the tubes, as those of the hepatic artery do into the portal-hepatic plexus of the lobules of the liver.

Thus there are in the kidney *two perfectly distinct systems of capillary vessels*, through both of which the blood passes in its course from the arteries into the veins: the 1st, that inserted into the dilated extremities of the uriniferous tubes, and in immediate connection with the arteries; the 2nd, that enveloping the convolutions of the tubes, and communicating directly with the veins. The efferent vessels of the Malpighian bodies, that carry the blood between these two systems, may collectively be termed the *portal system of the kidney*. To these distinct capillary systems, I am inclined to attribute distinct parts of the function of the organ; and their importance seems to warrant a few words, in further explanation of their anatomical differences.

The former, which may be styled the Malpighian capillary system, is made up of as many parts as there are Malpighian bodies. These parts are entirely isolated from one another; and, as there is no inosculation between the arterial branches supplying them, the blood enters each in a direct stream from the main trunk. This capillary system is also highly remarkable, indeed stands alone among similar structures, in being *bare*. The secreting tubes of the kidney, like those of all other glands, are,

strictly speaking, an involution of the outer tegument of the frame: their interior is, in one sense, the outside of the body: their walls intervene between the vessels and the exterior, and, as it were, cover them in. But here is a tuft of capillaries extruded through the wall of the tube, and lodged in a dilatation of its cavity, uncovered by any structure. Bare indeed, yet screened from injury in its remote cell, with infinite care and skill! Each separate part, also, of this system, has but one afferent and one efferent channel, and both of these are exceedingly small, compared with the united capacity of the capillary tuft. The artery in dividing, dilates: then follow branches which often exceed it in size, and which gradually break up into the finest. The efferent vessel does not usually even equal the afferent, and in size is often itself a capillary. Hence must arise a greater retardation of the blood in the tuft, than occurs probably in any other part of the vascular system; a delay that must be increased by the tortuosity of the channels to be traversed.

The other system of capillaries, or that surrounding the uriniferous tubes, corresponds, in every important respect, with that investing the secreting canals of other glands. It is well known to anatomists, and therefore does not require to be described at any length. Its vessels anastomose with the utmost freedom on every side, and lie on the deep surface of the membrane that furnishes the secretion.

I have applied the term '*portal system of the kidney*' to the series of vessels connecting these two, on account of the close analogy it seems to bear to the vena porta. The precise quality of the blood it carries may be doubtful, but in distribution it is similar. It intervenes between two capillary networks, the first of which answers to that in which the vena porta originates, and the second to that in which the vena porta terminates. The obvious difference lies in its several parts not uniting into a single trunk, to subdivide afterwards; but this circumstance seems to admit of an easy explanation. A trunk is formed in the great portal circulation, for the convenience of transport, most of the capillaries which supply it lying at a distance from the liver. Some, however, viz. those drawn from the hepatic artery, either enter the portal-hepatic plexus directly, (as Müller thinks, and as my preparations certainly show some of them to do,) or else join the minuter twigs of the portal vein, according to the opinion of Kiernan. Now, in the kidney, the vessels issuing from the Malpighian tufts are disseminated pretty equally throughout the plexus surrounding the tubes (the one into which they have to discharge themselves), and they therefore enter it at all points at once, without uniting. In the medullary cones, however, where there is a capillary plexus to be supplied with blood, but no Malpighian bodies nearer than the base of the cones, the conditions which oblige the formation of a portal venous trunk begin to operate; the two capillary systems it serves to connect are at some distance apart. Here, consequently, the Malpighian bodies are generally larger, their efferent vessels more capacious, and branched after the manner of an artery. *Each one of these efferent vessels is truly a portal vein in miniature.*

The capillary plexus surrounding the tubes differs, therefore, from that of other glands, and agrees with that of the liver, in its receiving blood that has previously traversed another system of capillary vessels. That other system is a peculiar one, as already pointed out, and cannot be likened closely to that which furnishes the portal vein of the liver.

The preceding account of the existence of a true portal system in the kidney of the higher tribes of Vertebrata was already written, when an opportunity presented itself of inspecting the distribution of the vessels in one of those lower animals, in which, besides the renal artery, the kidney is furnished with a portal vein, derived from the hinder part of the body. The presence of such a vein, though denied by Meckel, was well established by Nicolai, whose statements have been confirmed by others; but I am not aware that any anatomist has explained its remarkable distribution, and its connection with the other vessels*. I shall therefore introduce a summary account of my examination of the kidney of the Boa Constrictor (the animal in question), which may be regarded as a model of this variety; and I think it will be found not only to show the correctness of the analogy I have drawn between the efferent vessels of the Malpighian bodies and a portal system, but to place in a clearer light the other striking resemblances between the circulation of the liver and kidney.

The kidney of the Boa, being composed of isolated lobes, of a compressed reniform shape, displays all the points of its structure in peculiar simplicity and beauty. At what may be termed the hilus of each lobe, the branches of the vena porta and duct separate from those of the renal artery and emulgent vein; the two former spreading side by side, in a fan-like form, over the opposite surfaces of the lobe, while the two latter enter its substance, and radiate together in a plane midway between these surfaces. The lobe is made up of the ramifications of these four sets of vessels, in the following mode. Each *duct*, as it runs over the surface, sends down a series of branches which penetrate in a pretty direct manner towards the central plane. Arrived there, they curl back, and take a more or less retrograde course towards the surface, and finally, becoming more convoluted, terminate in the Malpighian bodies, which are all situated in a layer at some distance within the lobe, parallel to the central plane, and nearer to it than to the surface. The ducts never anastomose. The *artery* subdivides into extremely minute twigs, no larger than capillaries, which diverge on either hand, and enter the Malpighian bodies. The efferent vessels are of the same size as the afferent, and on emerging, take a direct course to the surface of the lobe, and join the branches of the vena porta there spread out. The branches of the *portal vein* on the surface, send inwards a very numerous series of twigs of nearly uniform capacity, and only a little larger than the vessels of the *capillary plexus*, in which

* Huschke, who seems to have entered into the greatest detail on this subject, states that he was unable to ascertain in the Serpent's kidney, whether the twigs of the artery were distributed to the Malpighian bodies or not. In the Frog, however, he describes the Malpighian bodies as appended to the terminal twigs of the artery. Isis, 1828, p. 566–7.

they almost immediately terminate. This is the plexus surrounding the uriniferous tubes. It extends from the surface to the central plane of the lobe, and there ends in the branches of the *emulgent vein.*

Thus the efferent vessels of the Malpighian bodies are radicles of the portal vein, and, through the portal vein, empty themselves, as in the higher tribes, into the plexus surrounding the uriniferous tubes. The only real difference between this form of kidney and that of Mammalia, is, that there is here a vessel bringing blood that has already passed through the capillaries of distant parts, to be added to that coming from the Malpighian bodies, and to circulate, with it, through the plexus surrounding the tubes. The efferent vessels of the Malpighian bodies run up to the surface in order to throw their blood through the whole extent of the capillary plexus; which they would fail to do, if they entered it in any other part.

I have described the renal artery as being spent upon the Malpighian bodies; but in the hilus of the lobe it gives off, as in the higher animals, a few slender twigs to the coats of the excretory ducts and of the larger vessels. The capillaries of these twigs are easily seen, and, in all probability, discharge themselves into the branches of the portal vein.

The circulation through this form of kidney, may be aptly compared with that through the liver, as described by Mr. Kiernan in his invaluable paper on that gland. The plexus surrounding the tubes corresponds with the portal-hepatic plexus, which, in the lobules of the liver, invests the terminal portions of the bile-ducts. Both these plexuses are supplied with blood by a portal vein, derived chiefly from the capillaries of distant organs, but in part from those of the artery of the respective organs themselves. The only difference seems to be, that, while, in the liver, the branches of the artery are entirely given to the larger blood-vessels, ducts, &c., in the kidney, a few only are so distributed, the greater number going through the Malpighian bodies. to perform an important and peculiar function. In both glands, however, all the blood of the artery eventually joins that of the portal vein. The emulgent vein of the kidney answers to the hepatic vein of the liver.

The *comparison between the hepatic and renal portal circulation* may be thus drawn in more general terms. The portal system of the liver has a double source, one extraneous, the other in the organ itself: so, the portal system of the kidney, in the lower tribes, has a two-fold origin, one extraneous, the other in the organ itself. In both cases the extraneous source is the principal one, and the artery furnishing the internal source is very small. But in the kidney of the higher tribes, the portal system has only an internal source, and the artery supplying it is proportionally large.

The above account appears to me to comprise whatever is most important in the anatomy of the blood-vessels and ducts of the kidney. My object in it has been to convey an idea of the physiological anatomy of the gland, and I have therefore omitted to mention (except where it suited my purpose) those rougher characters of the kidney in the various classes, that result from varieties in the mode of aggregation of

its several constituent parts. The principal of these are well known, and it would have diverted attention too much to delineate others, especially as such peculiarities are of trifling moment. The accompanying illustrations I have endeavoured to execute with scrupulous fidelity after nature. The injected specimens from which several of them are taken, are, with numerous others, in my possession, and those that can be examined only in a recent state, may usually be prepared with facility.

I shall now state the results of my injections of the kidney of Man and the higher animals by the arteries, veins, and ducts, in order to show their accordance with the view I have given of the nature of the Malpighian bodies, and of the vascular apparatus of the organ. This may be also desirable for purposes of comparison with the statements of other anatomists (which, to avoid prolixity, I have not referred to in detail); and it will, besides, give a full opportunity of testing the correctness of my statements, to those inquirers who may be disposed to do so*.

By the Arteries, *the Malpighian Tufts can be injected with great facility, and also, with less freedom, the Capillaries surrounding the uriniferous tubes. The Tubes also may be injected, by extravasation from the Malpighian tufts.*

The course of the injection to the tufts is direct and free. The arterial tree is of small capacity, and there is seldom so much blood in it after death as to impede the flow of the artificial fluid. My preparations show this tree injected in various degrees, by the double fluid (Plate IV. figs. 1 to 14). In some, the tufts are full, the afferent and the efferent vessels are both seen, as well as the communication of the latter with the plexus surrounding the tubes (figs. 2, 4, 5, 6). In others, the vessels of the tuft have given way under the pressure of the fluid, which has then escaped into the capsule and often into the tube also† (figs. 4, 9, 10, &c.). Sometimes the injection has passed freely and without extravasation through only a portion of the Malpighian tuft, leaving the rest filled with blood, which could not have happened to an unbranched coil of vessel, as this tuft is by some described‡. In these, the afferent and the efferent vessels are both injected, but only a fragment of the tuft (fig. 2). Sometimes the injected fluid has burst out immediately on entering the first branches

* It is worthy of notice, as showing both the difficulty of the subject and the uncertain state of our knowledge up to the present time, that Berres, the distinguished Professor of Vienna, in his recently published work on microscopical anatomy, maintains the existence of a direct inosculation of the uriniferous tubes with the capillary plexus surrounding them. After the description already given, I need hardly say, that this view seems to me, for many reasons, altogether untenable.

† I have great pleasure in stating that my friend Mr. Tomes, three years ago, during his examination of numerous kidneys that he had injected, saw two or three examples of this escape of the injection along the tube; of one of which he has preserved a rough outline. Not being able to see it again he gave up the search. I have no doubt that he communicated this fact to me in conversation at the time, though I cannot now recollect his doing so. The first drawing I made of the tube expanded over the tuft, I find dated February 17, 1841; about which time my interest in the subject was first excited.

‡ Of course this never occurs in Birds, where the Malpighian vessel is a coiled ampulla.

of the tuft: it has then insinuated itself between the ball of vessels and the capsule, and has run off along the tube. In this case the tuft is left uninjected and containing blood, and it becomes enveloped in a film of injection (fig. 9). Sometimes one side only of the tuft is injected at the moment when extravasation occurs, sometimes the whole, and likewise the efferent vessel (figs. 3, 4). In general, the capsule, when thus filled with extravasated injection, has a perfectly smooth external surface, but when the tuft within is also much distended, this may, in the dried and somewhat collapsed specimen, give to the outer surface of the capsule an uneven appearance like that of the tuft itself. The capsule, when distended, is seen in many instances to bulge and form a prominent circle round the point at which the vessels enter and emerge. The vessels then appear to lie in a small pit or fissure before becoming connected with the tuft (fig. 9). Lastly, it occasionally happens that though extravasation has occurred into the capsule, the fluid has not spread itself over the whole surface of the tuft, and yet has passed off along the tube (figs. 3, 10, *m*, *m*). As the tubes in the human kidney usually become very tortuous immediately on leaving the Malpighian bodies, the injection running off along them may often wear the appearance of an irregular extravasated mass, and so its real nature escape observation*

* During the course of the researches detailed in this paper, I have embraced whatever opportunities presented themselves of studying the morbid conditions of the human kidney, and especially those usually known as the stages of Bright's disease. It would obviously have been little conducive to my present purpose to have entered here upon a general description of the results to which my inquiries on this interesting subject have led me, but I cannot forbear noticing one fact of considerable importance, which will both illustrate and be illustrated by the preceding account of the normal anatomy of the gland. It is well known that blood is often passed with the urine during the course of the disease, especially at the earlier periods of it, when many circumstances contribute to prove that the kidneys are in a state of sanguineous turgescence. How does this blood escape into the ducts of the gland? The organ examined at this time presents on its surface and throughout its cortical substance, scattered red dots, of somewhat irregular shape, not accurately rounded, and generally as large as pins' heads, that is, very many times larger than the Malpighian bodies. These spots are very visible on the surface, where, as I have before stated (p. 62), no Malpighian bodies exist. They have been nevertheless described by several recent writers (not without contention for the honour of the discovery) as Malpighian bodies enlarged from congestion. How a Malpighian tuft, such as I have described it, could attain so prodigious a bulk, prodigious compared with its natural size, it would not be easy to explain. It is true that, if examined with a lens, the blood forming these spots is found to be arranged in convoluted lines, but these convolutions are not the dilated vessels of the tuft. They are nothing less than *the convolutions of a tube filled with blood*, that has burst into it from the gorged Malpighian tuft at its extremity. This is at once evident to a person familiar with the appearance of the same tubes when filled with injection in a similar manner; and the figure, which I have taken from a healthy kidney so injected (fig. 11), might serve as an exact representation of one of these spots, as seen on the surface of the diseased organ. The more or less perfect plug, thus often formed in the tubes, is the occasion of those dilatations of the *tubes* and Malpighian *capsules*, which are to be met with in the more advanced stages of the disease. Thus is to be explained the somewhat loose statement, that the disease consists essentially in enlargement of the Malpighian bodies. Though I have examined with great care many kidneys at all stages of the complaint, I have never seen, in any one instance, a clearly dilated condition of the Malpighian tuft of vessels. On the contrary, my friend, Mr. Busk, an excellent observer, has specimens which undoubtedly prove these tufts not to be dilated in the first stage, and I possess injected specimens showing them at all stages, but never above their natural size. I am far from implying,

(fig. 9). When size and vermilion are employed, this is very apt to occur*, and especially when the specimen injected is not fresh; for the epithelium soon loses its adhesion to the basement tissue of the tube, and, falling into the cavity, mingles with the stream of injection, and renders its course obscure. This lining of the tubules with a pavement of epithelium occasions a striking appearance in perfectly fresh specimens, when filled with double injection. This penetrating material insinuates itself into the interstices of the epithelial particles, and thus marks them out as a kind of pattern on the wall of the tube. When extravasation does not take place in the Malpighian bodies, more or less of the network surrounding the tubes is not unfrequently injected. The most perfect specimens of injected Malpighian tufts are then obtained; but the veins themselves are seldom well filled through the arteries, for not only is the way to them circuitous, and broken up into a thousand separate avenues (the Malpighian tufts), but it is usually loaded with blood. When injection is driven into any one branch of the renal artery, the several states now detailed are seen only in the parts to which that branch is distributed. There is no anastomosis between the branches in the interior of the gland.

It sometimes happens that in injections by the artery, extravasation is found to take place into the interstices of the tubes, with or without escape into the Malpighian capsules and tubes. This may arise from rupture either of the arterial tree, before reaching the Malpighian bodies (which is uncommon, where great force is not employed), or of the efferent vessels of those bodies, or of the network of the tubes, injected through them. It may also occur from rupture of a tube, which has been itself filled by the rupture of a Malpighian tuft.

By the Veins, *the Capillaries surrounding the tubes may be injected, but neither the Malpighian bodies, nor the arteries, nor, without extravasation, the tubes.*

The capillaries of the uriniferous tubes are of great aggregate capacity, and commonly contain much blood. When injection is pushed into the vein the whole organ instantly swells; so rapidly do these dilatable and freely inosculating channels receive the fluid impelled into them. By the numerous communications of the capillaries with the veins, it is at once dispersed in every direction, and enters the capil-

however, that these bodies are unconcerned in the train of morbid phenomena. They unquestionably are so, and even necessarily must be so, from their anatomical structure, but in what manner I shall not at present attempt to show.

* My friend Mr. Quekett, of the College of Surgeons, possesses many very excellent specimens of injected kidneys, in many of which he has been able to detect the tube passing from the Malpighian body, since his attention was directed to this arrangement. He also showed me a very beautiful injection of the Malpighian bodies in the Horse, sent over to the Microscopical Society of London by Prof. Hyrtl of Prague. In one corner of this we found a similar extravasation, though the disposition in question seems to have eluded the attention of that excellent anatomist. I am indebted to Mr. Quekett for some finely injected specimens of a boa's kidney, from one of which fig. 14. is taken.

laries by innumerable avenues. But towards the Malpighian bodies, there is no opening from this capillary network at all corresponding in magnitude or freedom to that on the side of the veins. In fact, the only points by which it can discharge itself are the efferent vessels of the Malpighian bodies, which are comparatively few in number, only capillary in size, and quite disconnected with one another, except through the plexus itself. Add to this, that the Malpighian tuft to which they lead is a great obstacle to the passage of fluid, from the tortuosity of its minute vessels, and by their all having but one point to discharge themselves of the blood they already contain, viz. their afferent vessel. Thus to fluid driven through the kidney in a retrograde course, there is not only the general impediment offered by the aggregate capacity of the arteries being greatly inferior to that of the veins, but a vascular arrangement equivalent to a double valve. The capillaries of the tubes form a first great cul-de-sac, those of the Malpighian tufts a second, for these may both be described as great reservoirs, easily entered from the side of the arteries, but discharging themselves with great difficulty back again, or towards the arterial tree. If it be now considered that the network of the tubes, or the former and far the greater of these reservoirs, almost always retains much blood after death, and that the Malpighian reservoir is never without a considerable quantity, it will not be difficult to comprehend, why injection thrown into the veins reaches not to the Malpighian bodies, however well it may seem to load the capillaries of the tubes; for all the blood must first pass through the difficult channels that have been spoken of, and this it never can do completely. I suppose that this view of the subject, which is nothing more than a statement of facts, will be deemed a sufficient explanation, and that it will not be regarded as necessary to imagine the existence of real valves in any part of the course of these small blood-vessels. I have never met with any appearance that could lend credibility to such a supposition, which, if true, would present an unique structure in the vascular system. Extravasation from the veins will sometimes reach the tubes, in consequence of a structure which will presently be explained.

By the Tubes, *the Malpighian bodies cannot be injected, nor, without extravasation, either the plexus surrounding the tubes, or the veins.*

Many anatomists have taken extreme pains to inject the tubes from the pelvis of the kidney, by means of the air-pump, but never has a single Malpighian body been thus filled. This, it has been said, is a conclusive proof that the Malpighian bodies are not placed at the extremities of the tubes. But I think that if the real structure and relation of these parts be duly considered, this constant result will be allowed to be in the strictest accordance with the account I have delivered, and even a necessary effect of the anatomical disposition of the parts. To those who are acquainted with the practical difficulties of the injection of the ducts of glands in general, and especially of those which are very tortuous, the following considerations on this subject

will probably appear conclusive. Even of the testis (where the tubes are far thicker and stronger in their coats, and much more capacious than in the kidney), there are not ten specimens that can be pronounced at all full, in the museums of Europe; and there is no evidence, that, even in the best of these, the injected material has reached the very extremities of the tubes.

In the kidney, the tubes are exceedingly tortuous after leaving the Malpighian bodies, and only become straight, in most animals, in proceeding towards the excretory channel to discharge themselves. The way towards their orifices is so free, in a natural state, that their fluid contents exert no distending force upon their walls. Accordingly their walls are exceedingly feeble; the basement membrane on which their strength mainly depends, is very delicate and easily torn. They are therefore incapable of offering much resistance to a fluid impelled into them from the pelvis, but burst readily, if it be forcibly urged. But were the coats ten times as tough as they really are, injection could not penetrate far into their convoluted portion, unless pushed with much force; and this for two reasons:—1st. The fluid which the tubes already contain has no means of escape before the injection, since these canals end by blind extremities in the Malpighian bodies; and though these bodies are dilatations of them, yet they are already filled almost completely by the tuft of capillaries, and offer no capacious receptacle for the fluid from the tubes. 2nd. The layer of epithelium (which usually forms about two-thirds of the thickness of every tube, the calibre being about one-third*) is, immediately after death, very prone to separate from the basement membrane which it lines, and to fall into and block up its narrow channel. Even if the epithelium remains in its place, the calibre of the tube is but small, and if it becomes detached, it opposes an effectual bar to the progress of the injection. By removing the pressure of the atmosphere from the outer surface of the tubes, these obstacles are occasionally in part overcome, so that even the tortuosities of the tubes are filled for a certain distance. But even so limited a success is rare, and in face of mechanical obstacles, such as above mentioned, to the onward current of the injection in the tubes, the force employed invariably sooner or later bursts their coats, ere their extremities have been reached. Extravasation from the tubes, as might be expected, fills their interstices, and the fluid may then issue by a rent at the hilus of the kidney. But it is remarkable how readily it enters the veins and absorbents from the ducts. This is undoubtedly by extravasation, and does not prove any continuity between them. The veins may be filled when the fluid has not penetrated in the tubes beyond the medullary cones, showing that the rupture must occur in connection with those cones, either at their apices or in their substance. By a thin transverse section of one of these cones, the ducts and blood-vessels of which they principally consist, are seen to be imbedded in a sort of matrix, apparently homogeneous, but probably having a cellular structure. This matrix keeps the tubes and

* These proportions vary considerably. The basement membrane is so thin that it may be left out of the estimate.

vessels open by being united to their outer coat, whence results the dark colour, usually attributed to congestion, which these cones commonly present, as compared with the cortical part, where this matrix is less abundant. This is the structural condition which seems to me most easily to explain the remarkable facility with which injection, urged along the tubes, enters the veins. The smallest rupture of the matrix will crack across the minute vessels accompanying the tubes, and expose their open extremities to the entrance of the injection. If the force employed be very moderate and equable, extravasation does not occur, and the tubes alone are injected, often to the surface, but undue or ill regulated pressure almost inevitably occasions it. Having once entered a small vein, through however small an opening, it soon diffuses itself through the veins, and the capillaries surrounding the tubes, rather than along the tubes, for the reasons above stated; and, if the organ be then cut to pieces and examined, these vessels seem filled, without extravasation; the tubes are also more or less filled with the same colour; and the two structures are so intricately interlaced, as to wear the aspect, especially if dried, of one continuous network. The point of extravasation escapes observation, and hence the fallacy of imagining a continuity between the veins or their capillaries, and the tubes.

Some distinguished anatomists have held that the tubes end in a plexiform manner, and have stated themselves to have unequivocally seen this arrangement in injected specimens. I am induced to believe this opinion to be founded on deceptive appearances; either such as that above mentioned, or that occasioned by the overlapping of injected tubes. Others have considered the tubes to terminate in free blind extremities unconnected with the Malpighian bodies, and have likewise rested their opinion on the appearances of injected specimens, as well as on those of recent ones. As the injection always stops short of the real extremities of the tubes (the Malpighian bodies), it must necessarily show apparent free extremities—and others may be produced by the section requisite for the examination of the part. As for the false appearances presented by recent specimens, they are obviously referable to the sudden bending down of a tube behind the part turned to the observer. In a mass composed of convolutions, many such must continually occur; and their real nature may be easily determined by the use of a high power and varying focus. Other anatomists, aware of this last fallacy, and failing to find either a free inosculation of the tubes in the form of a plexus, or a termination of them in the Malpighian bodies, have rested in the conclusion that the curves of the convoluted part are the looped junctions of different tubes. It is obvious that this conclusion is a deduction drawn from the apparent absence of any other mode of termination, and must be relinquished now that the tubes are shown to end in the Malpighian bodies.

The foregoing account has been drawn principally from my observations on the kidneys of Mammalia, but it is intended to embrace the chief points in the anatomy of the Malpighian bodies in all the Vertebrate tribes. In all these, I have ascertained

the Malpighian body to consist of the dilated extremity of the uriniferous tube, with a small mass of blood-vessels inserted into it. But in the several orders of animals, there are various modifications that merit notice. The most considerable of these regard the size of the Malpighian bodies, in connection with which are others in the mode of division of the arterial twig. The following Table exhibits this variety in their size, in a few species, and subjoined to each measurement, is that of the tube soon after its emergence. It will be seen that the tubes differ far less than the Malpighian bodies.

Table of the Diameter of Malpighian Bodies, and of the Tubes emerging from them in Fractions of an English Inch.

	Diameter of Malpighian bodies.			Diameter of tubes.
	Maximum.	Mean.	Minimum.	
Man	$\frac{1}{80}$	$\frac{1}{104}$	$\frac{1}{144}$	$\frac{1}{480}$
Badger	$\frac{1}{104}$	$\frac{1}{124}$	$\frac{1}{150}$	$\frac{1}{416}$
Dog	$\frac{1}{120}$	$\frac{1}{135}$	$\frac{1}{156}$	$\frac{1}{600}$
Lion	$\frac{1}{70}$	$\frac{1}{80}$	$\frac{1}{90}$	$\frac{1}{312}$
Cat	$\frac{1}{156}$	$\frac{1}{200}$	$\frac{1}{250}$	$\frac{1}{680}$
Kitten	$\frac{1}{208}$	$\frac{1}{260}$	$\frac{1}{312}$	$\frac{1}{1000}$
Rat	$\frac{1}{208}$	$\frac{1}{180}$	$\frac{1}{150}$	$\frac{1}{416}$
Mouse (*Mus*)	$\frac{1}{220}$	$\frac{1}{255}$	$\frac{1}{312}$	$\frac{1}{770}$
Squirrel (*Sciurus vulgaris*)	....	$\frac{1}{207}$	....	$\frac{1}{770}$
Rabbit (*Lepus Cuniculus*)	....	$\frac{1}{156}$	....	$\frac{1}{625}$
Guinea Pig (*Cobaya*)	....	$\frac{1}{208}$	....	$\frac{1}{600}$
Horse	$\frac{1}{55}$	$\frac{1}{70}$	$\frac{1}{90}$	$\frac{1}{416}$
Parrot (*Psittacus*)	....	$\frac{1}{430}$	....	$\frac{1}{600}$ to $\frac{1}{700}$
Tortoise (*Testudo*)	....	$\frac{1}{240}$	....	$\frac{1}{480}$
Boa	$\frac{1}{230}$	$\frac{1}{400}$	$\frac{1}{540}$	$\frac{1}{540}$
Frog (*Rana*)	....	$\frac{1}{250}$		
Eel (*Anguilla vulgaris*)	....	$\frac{1}{207}$		

The kidney of the Boa shows very beautifully the reason of the different size of the Malpighian bodies in different parts of the same gland observed in all animals; and also one cause of the striking difference in their size in different animals, and especially in different-sized animals of the same natural group. Its lobes are much thinner at their convex border, opposite the hilus, than elsewhere. The tubes are consequently much shorter there, and I have remarked that the Malpighian tufts are also much smaller. This correspondence between the size of the Malpighian bodies and the length of the tubes, throws much light on the function of the former. A further study of the varieties here displayed in the size of the Malpighian tufts seems highly desirable.

Reflecting on this remarkable structure of the Malpighian bodies, and on their singular connection with the tubes, I was led to speculate on their use. It occurred to me that as the tubes and their plexus of capillaries were probably, for reasons presently to be stated, the parts concerned in the secretion of that portion of the urine to which its characteristic properties are due (the urea, lithic acid, &c.), the Malpighian bodies might be an apparatus destined to separate from the blood the watery portion. This view, on further consideration, appears so consonant with facts, and with analogy, that I shall in a few words state to the Society the reasons that have induced me to adopt it. I am not unaware how obscure are the regions of hypothesis in physiology, and shall be most ready to renounce my opinion, if it be shown to be inconsistent with truth.

In extent of surface, internal structure, and the nature of its vascular network, the membrane of the uriniferous tubes corresponds with that forming the secreting surface of other glands. Hence it seems certain that this membrane is the part specially concerned in eliminating from the blood the peculiar principles found in the urine. To establish this analogy, and the conclusion deduced from it, a few words will suffice. 1. The extent of surface obtained by the involutions of the membrane, will by most be regarded as, itself, sufficient proof. But, 2. Its internal structure is conclusive. Since epithelium has been found by Purkinje and Henle in such enormous quantities on the secreting surface of all true glands, its use cannot be considered doubtful. It never forms less than $\frac{19}{20}$ths of the thickness of the secreting membrane, and in the liver it even seems to compose it entirely, for there I have searched in vain for a basement tissue, like that which supports the epithelium in other glands. As I have endeavoured to show in the forthcoming Number of the Cyclopædia of Anatomy, the epithelium thus chiefly forming the substance of secreting membrane, differs in its general characters from other forms of this structure. Its nucleated particles are never clothed with cilia, and are not surrounded with a definite cell-membrane. They are more bulky, and appear from their refractive properties to contain more substance, their internal texture being very finely mottled, when seen by transmitted light. In these particulars, the epithelium of the kidney-tubes is eminently allied to the best-marked examples of glandular epithelium. 3. The capillary network surrounding the uriniferous tubes is the counterpart of that investing the tubes of the testis, allowance being made for the difference in the capacity of these canals in the two glands. It corresponds with that of all true glands in lying on the deep surface of the secreting membrane, and in its numerous vessels everywhere anastomosing freely with one another.

These several points of identity may seem too obvious to be dwelt upon, but I have detailed them in order to show, that in all these respects, the Malpighian bodies differ from the secreting parts of true glands. 1. The Malpighian bodies comprise but a small part of the inner surface of the kidney, there being but one to each tortuous tube. 2. The epithelium immediately changes its characters, as the tube ex-

pands to embrace the tuft of vessels. From being opake and minutely mottled, it becomes transparent, and assumes a definite outline. From being bald, it becomes covered with cilia (at least in reptiles, and probably in all classes); and, in many cases, it appears to cease entirely, a short way within the neck of the Malpighian capsule. 3. The blood-vessels, instead of being on the deep surface of the membrane, pass through it, and form a tuft on its free surface. Instead of the free anastomosis elsewhere observed, neighbouring tufts never communicate, and even the branchlets of the same tuft remain quite isolated from one another.

Thus the Malpighian bodies are as unlike, as the tubes passing from them are like, the membrane, which, in other glands, secerns its several characteristic products from the blood. To these bodies, therefore, some other and distinct function is with the highest probability to be attributed.

When the Malpighian bodies were considered merely as convoluted vessels without any connection with the uriniferous tubes, no other office could be assigned them, than that of delaying the blood in its course to the capillaries of the tubes, and the object of this it was impossible to ascertain. Now, however, that it is proved that each one is situated at the remotest extremity of a tube, that the tufts of vessels are a distinct system of capillaries inserted into the interior of the tube, surrounded by a capsule, formed by its membrane and closed everywhere except at the orifice of the tube, it is evident that conjectures on their use may be framed with greater plausibility.

The peculiar arrangement of the vessels in the Malpighian tufts is clearly designed to produce a retardation in the flow of the blood through them. And the insertion of the tuft into the extremity of the tube, is a plain indication that this delay is subservient in a direct manner to some part of the secretive process.

It now becomes interesting to inquire, in what respect the secretion of the kidney differs from that of all other glands, that so anomalous an apparatus should be appended to its secerning tubes? The difference seems obviously to lie in the quantity of aqueous particles contained in it; for how peculiar soever to the kidney the proximate principles of the urine may be, they are not more so than those of other glands to the organs which furnish them.

This abundance of water is apparently intended to serve chiefly as a menstruum for the proximate principles and salts which this secretion contains, and which, speaking generally, are far less soluble than those of any other animal product. This is so true, that it is common for healthy urine to deposit some part of its dissolved contents on cooling. It may seem that an exception to this exists in the solid urine of some reptiles; but this expression merely describes the urine as it is found in the cloaca and larger excretory channels. The secretion is brought from the tubules of the gland in a fluid state, and only becomes solid by the re-absorption of its aqueous portion after it has traversed the tortuous canals wherein it was formed, and been placed in a condition to be readily expelled from the system. The subordination of the aqueous part to the purpose of eliminating the more essential elements

of the secretion from the secerning tubules of the gland, is therefore here placed in a clear light.

If this view of the share taken by the water be correct, we must suppose that fluid to be separated either at every point of the secreting surface, along with the proximate principles, as has hitherto been imagined, or else in such a situation that it may at once freely irrigate the whole extent of the secerning membrane. Analogy lends no countenance to the former supposition, while to the latter, the singular position, and all the details of the structure of the Malpighian bodies, give strong credibility.

It would indeed be difficult to conceive a disposition of parts more calculated to favour the escape of water from the blood, than that of the Malpighian body. A large artery breaks up in a very direct manner into a number of minute branches, each of which suddenly opens into an assemblage of vessels of far greater aggregate capacity than itself, and from which there is but one narrow exit. Hence must arise a very abrupt retardation in the velocity of the current of blood. The vessels in which this delay occurs are uncovered by any structure. They lie bare in a cell from which there is but one outlet, the orifice of the tube. This orifice is encircled by cilia, in active motion, directing a current towards the tube. These exquisite organs must not only serve to carry forward the fluid already in the cell, and in which the vascular tuft is bathed, but must tend to remove pressure from the free surface of the vessels, and so to encourage the escape of their more fluid contents. Why is so wonderful an apparatus placed at the extremity of each uriniferous tube, if not to furnish water, to aid in the separation and solution of the urinous products from the epithelium of the tube?

Many recently discovered facts* conspire to prove that secretion is a function very nearly allied to ordinary growth and nutrition; that whereas growth and nutrition comprehend two functions, assimilation of new particles and rejection of old, the old being reconveyed into the blood, so secretion consists in a corresponding assimilation and rejection, and only differs in the old particles being at once thrown off from the system, without re-entering the blood. According to this view, all effete material received into the blood from the old substance of the various organs, must be reassimilated by an organized tissue, specially designed for the purpose, before it can be

* Purkinje, Report of the Meeting of Naturalists at Prague in 1837, Isis, No. 7, 1838. Schwann, Froriep's Notiz. Feb. 1838. Henle, Müller's Archiv. 1838–9. [See also Cyclop. of Anatomy, Art. *Mucous membrane*, the conclusion of which is only just published, although that part of it relating to this theory was written in December last. Mr. Goodsir, since this paper was read, has ably advocated this theory in a communication made to the Royal Society of Edinburgh on the 30th of March, an abstract of which I have just seen in the London and Edinburgh Monthly Journal of Medical Science, May 1842. In the same publication is a report of a paper by the same excellent anatomist, on the structure of the kidney, read at the Med. Chir. Soc. of Edinb. on April the 6th. He describes "a fibro-cellular framework, pervading every part of the gland"—analogous to the capsule of Glisson, and "forming small chambers in the cortical portion, in each of which a single ultimate coil or loop of the uriniferous ducts is lodged." This framework is the structure which I have described (pp. 70–1) as the *matrix*. The convoluted tubes and vessels are all imbedded in it.—*June* 1, 1842.]

eliminated: and all secretions designed for an ulterior use in the œconomy must be assimilated by such a tissue in order to their separation from the blood. This tissue is the epithelium of such surfaces, as, from their external anatomical position, can at once release the secretion, when its elaboration is accomplished. The epidermis of the skin, the epithelium of mucous membranes, and that of true glands, all more or less completely fulfil this purpose; but the first is chiefly designed as a protection, the second partly so, and the third is the only one entirely devoted to what is properly called secretion. Into the examination of this general question, it is impossible that I should now enter, but I shall state some considerations connected with it, that seem to have a bearing on the present subject.

This theory, in its widest sense, supposes the epithelium of secreting surfaces either to pass through constant stages of renovation and decay, or else to remain, during a longer period, as a permanent organic form, assimilating and rejecting, in the mode just described. In many cases the epithelial particles appear to be cast off entire when their growth is complete, and thus to form the secretion; in other instances, they seem to lose their substance by a more gradual process, and to waste or dissolve away on the surface of the membrane, as fresh particles are deposited below; in other examples still, there is reason for believing that they are long a persistent structure. It supposes that the elements of all natural secretions have at one time been a part of an organized form, the epithelial particle; but it leaves it uncertain, whether the secretion, in a complete state, always exists in such particles when alive. It does not determine whether the chemical changes which occur in such particles, issue in the completion of the secreted product, until the period arrives for its being shed from the body. Hence it is beyond the reach of objections founded on the chemical examination of glandular organs *en masse*.

Applying this theory to the kidney, it may be considered highly probable that the epithelium of the uriniferous tubes is continually giving up its effete particles, and undergoing a gradual decay. This view harmonizes in a striking manner with what has been before advanced as to the use of the Malpighian bodies. If the peculiar urinous principles were poured out at once, through the walls of the tubes by the capillaries surrounding them, they must be in a dissolved state from the first, and could need no further aqueous current to carry them off; but if they are deposited in a more or less solid form, as a part of an organized tissue, they will require (being so sparingly soluble) an additional and extraneous source of water, by which, when their formation is complete, they may be taken up and conveyed from the gland. The correspondence before noticed (p. 72) between the size of the Malpighian bodies and the length of the tubes coming from them, is a strong argument in favour of this view.

I stated that the large quantity of water in the urine seemed *chiefly* to serve the purpose of a menstruum. But though this quantity is always large, compared with that in other secretions, it is liable to great variation, according to the state of fulness

of the vascular system, and other circumstances. Hence the kidneys appear to share in the office of regulating the amount of water in the body. How admirably the structure of the Malpighian bodies fits them for thus acting as a self-adjusting valve or sluice to the circulation, I need not explain.

It may possibly be considered by some, that, in the preceding observations on the use of the aqueous element of the urine, and on the nature of secretion in general, I have been endeavouring to illustrate a doubtful hypothesis by speculations more doubtful still, *obscurum per obscurius*. But I rest my view of the function of the Malpighian bodies principally on anatomical grounds, and the other considerations have been introduced in connection with it, rather in consequence of the interest they appear to me to add to it, than because I am fully satisfied of their validity. Undoubtedly both questions are worthy of being separately handled, and require a much wider and more elaborate investigation than seems yet to have been given them. Meanwhile they may in turn receive some elucidation from the researches detailed in this paper. Parallel lines of inquiry into the anatomical varieties of the Malpighian bodies and uriniferous tubes, and into the chemistry of their secretion, in the different tribes of animals and in various stages of their development, could scarcely fail either to confirm or to confute what has now been advanced.

I shall conclude with three remarks founded on the foregoing facts and speculations.

1. The bile and the urine have been ever classed together as the most important excretions. The former is secreted from venous blood; the latter it has been thought from arterial blood, except in some inferior animals, in which the blood from the lower part of the body circulates through the kidneys. But it is a most striking fact, that the proximate principles of the urine, like those of the bile, are secreted *in all animals* from blood which has already passed through one system of capillaries, in a word, from portal blood; although it does not appear to what extent its qualities are changed by traversing the Malpighian system. The analogy is at least remarkable, and may throw some light on the mysterious meaning of the portal circulation.

2. *Diuretic medicines* appear to act specially on the Malpighian bodies; and *various foreign substances*, particularly salts, which, when introduced into the blood, pass off by the urine with great freedom, exude in all probability through this bare system of capillaries. The structure of the Malpighian bodies indicates this, and also, as far as they are known, the laws regulating the transmission of fluids through organized tissues, modified in their affinities by vitality.

3. The escape, also, of certain morbid products, occasionally found in the urine, seems to be from the Malpighian tufts. I allude especially to *sugar*, *albumen*, and *the red particles of the blood*: the two first of which would transude, while the last would escape only by rupture of the vessels*.

* See Note, p. 67.

3 *Norfolk Street, Strand,*
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Explanation of the Plate.

PLATE. IV.

Fig. 1. Malpighian tuft—Horse. The injection has penetrated only to the capillaries. *a.* The artery. *af.* One of its terminal twigs (or the afferent vessel of the Malpighian body). *d.* The dilatation and mode of breaking up of the terminal twig, after entering the capsule: the division of the tuft into lobes *l, l, l, l,* is well seen. *i, i.* Intervals between the lobes. Magnified about eighty diameters.

Fig. 2. Malpighian tuft—Horse. The injection has penetrated through the tuft and has filled the efferent vessel, here coloured yellow for distinctness' sake. *af.* The afferent vessel. *d.* Its dilatation and mode of division. *m, m.* Malpighian capillaries. *ef.* Efferent vessel springing from them, and leaving the capsule between two primary branches of the afferent vessel. Magnified about eighty diameters.

Fig. 3. Malpighian body—Horse. The injection, after filling the primary branches of the afferent vessel, has burst into the capsule and passed off along the tube. It has not filled the tuft of capillaries, which consequently are not seen, nor has it spread within the capsule over the whole surface of the tuft. *af.* The afferent vessel. *d.* Its dilatation and mode of subdivision. *c, c.* The outline of the distended capsule. *t.* The tube passing from it. *m.* Situation of the uninjected Malpighian tuft. Magnified about seventy diameters.

Fig. 4. From the Horse. The injection has penetrated from the artery, through the Malpighian tuft, into the plexus surrounding the tubes. It has then ruptured the vessels of the tuft, filled the capsule, and passed off along the tube. *a.* Arterial branch. *af.* Afferent vessel. *c.* Capsule distended. *t.* Tube. *ef.* Efferent vessel. *p.* Plexus of capillaries, surrounding other tubes not injected. Magnified about thirty diameters.

Fig. 5. From the Horse. The injection has passed as in the last-described specimen, but without rupture of the Malpighian tuft. *a.* Branch of the artery. *af, af.* Afferent vessels. *m, m.* Malpighian tufts. *ef, ef.* Efferent vessels. *p.* Plexus surrounding the tubes. *st.* Straight tube in cortical substance. *ct.* Convoluted tube in ditto. Magnified about thirty diameters.

Fig. 6. From the Horse. Malpighian tuft, from near the base of one of the medullary cones, injected without extravasation, and showing the efferent vein branching like an artery, as it runs into the medullary cone. *a.* Arterial branch. *af.* The afferent vessel. *m, m.* The Malpighian tuft. *ef.* The efferent vessel. *b.* Its branches entering the medullary cone. Magnified about seventy diameters.

Fig. 7. Similar specimens from the Rabbit, but with extravasation into the capsule, and at *t* into the tube also. *af*, *af*. Afferent vessel. *c*, *c*. The capsule. *t*. The tube. *ef*, *ef*. The efferent vessel. *b*, *b*. Its branches entering the medullary cone. Magnified about thirty diameters.

Fig. 8. From the Horse. Two Malpighian tufts springing close together from a single terminal twig of the artery. An unusual arrangement. *af*. Afferent vessel. *m*, *m*. Malpighian tufts. Magnified about thirty diameters.

Fig. 9. From the human subject. Two Malpighian bodies injected. The tufts are burst and the fluid has escaped into the capsule. In one case it has passed also along the tube, the extreme tortuosity of which at its commencement, is well seen. *a*. Arterial branch. *af*. Terminal twigs. *c*, *c*. Malpighian capsules distended. *de*. The depression often seen in such cases, at the point where the afferent and efferent vessels pass: the latter are not here injected. *t*. The tube. Magnified about ninety diameters.

Fig. 10. From the human subject. This specimen has been chosen because it exhibits the termination of a considerable arterial branch, wholly in Malpighian tufts, and because the several Malpighian bodies injected show different appearances of a very instructive kind. *a*. Arterial branch with its terminal twigs. At α the injection has only partially filled the tuft. At β it has entirely filled it, and has also passed out along the efferent vessel *ef*, without any extravasation. At γ it has burst into the capsule and escaped along the tube *t*, but has also filled the efferent vessel *ef*. At δ and ε it has been extravasated and passed along the tube. At *m* and *m* (as in fig. 3) the injection on escaping into the capsule has not spread over the whole tuft. Magnified about forty-five diameters.

Fig. 11. A minute portion of the *surface* of the human kidney, injected from the *artery*. The injection has burst many Malpighian tufts within the cortical substance, and so filled the tubes, the convolutions of which on the surface of the organ are here displayed. It has also traversed other Malpighian tufts without extravasation, and so filled the capillary plexus surrounding the tubes and some radicles of the vein. *t*, *t*. Tortuous tubes as seen on the surface: these, with their capillaries, cover the surface, so that no Malpighian bodies appear. *p*. Capillary plexus surrounding the tubes, as seen on the surface. *ev*. A branch of one of the stelliform veins. Magnified about forty-five diameters.

Fig. 12. From the Guinea Pig (*Cobaya*). Terminal branch of the renal artery injected. The injection has burst most of the Malpighian tufts and passed off along the tubes. *a*. Arterial branch. At *m* are seen a few Malpighian tufts partially injected without extravasation. Magnified about forty diameters.

Fig. 13. From the Parrot (*Psittacus*). Injected by the artery. *a*, *a*, *a*. Terminal branches of the artery. *af*, *af*, *af*. Terminal twigs of the artery. *d*. Dila-

tation of the terminal twig on entering the Malpighian capsule. *m*. This dilatation more completely filled, showing its convoluted form, and *ef.* the efferent vessel. *c*. The Malpighian capsule filled, by extravasation from the contained vessel, and the tube *t* likewise filled. *c'*. The same, with the efferent vessel *ef*, also filled. Magnified about eighty diameters.

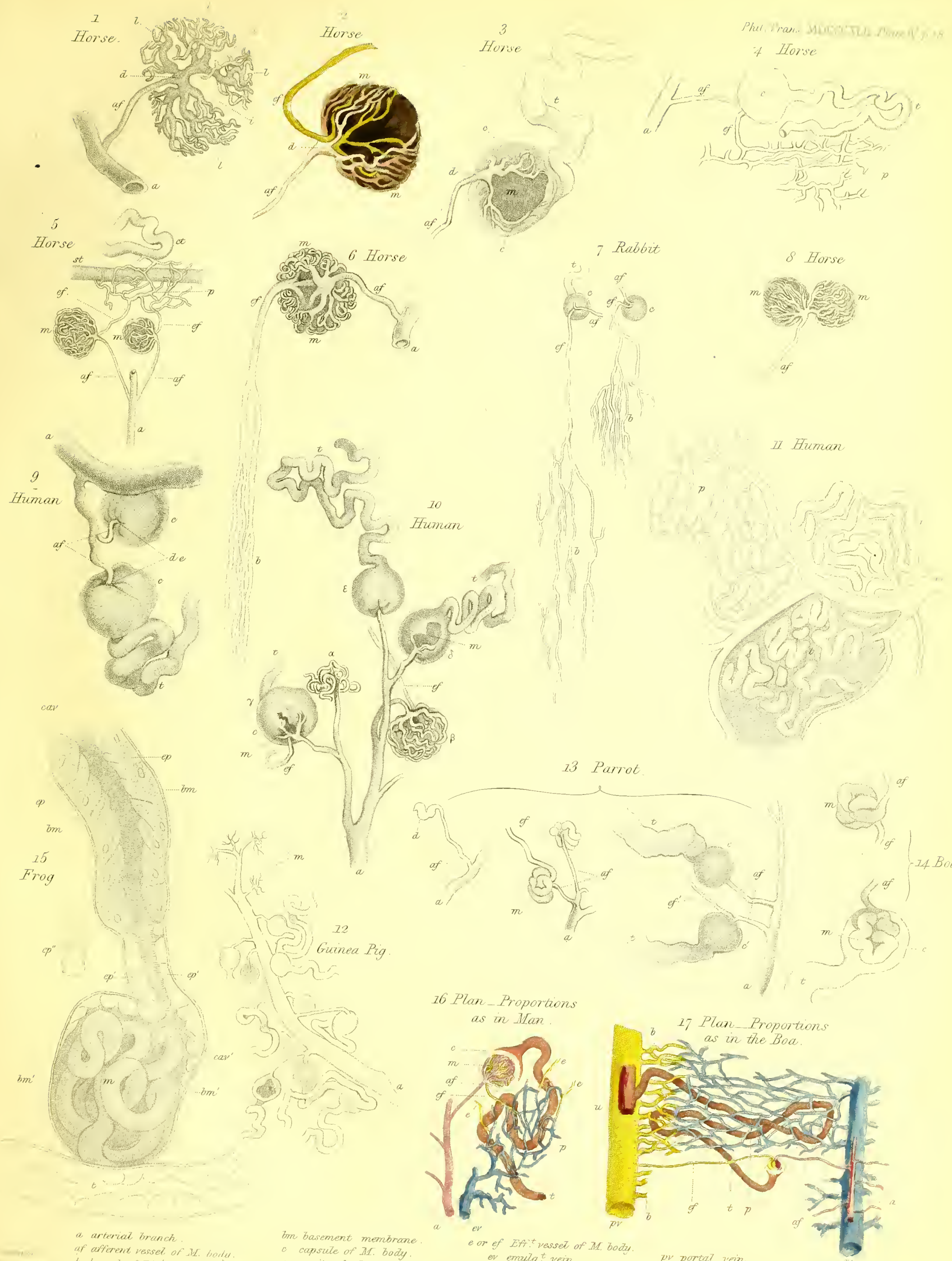
Fig. 14. From the Boa Constrictor. Injected by the artery. *af*, *af*. Terminal twigs of the artery. *m*, *m*. The convoluted dilated part within the Malpighian capsule. *ef*. The efferent vessel. *c*. The capsule—visible, but not injected. *t*. The commencement of the tube. Magnified about seventy diameters.

[All the preceding figures are viewed by reflected light.]

Fig. 15. From the Frog; viewed by transmitted light. Shows the continuity of the Malpighian capsule with the tube, the change in the character of the epithelium, and the vascular tuft. *bm*, *bm*. Basement membrane of the tube. *ep*, *ep*. Epithelium of the tube. *cav*. Cavity of the tube. *bm'*, *bm'*. Basement membrane of the capsule. *ep'*, *ep'*. Epithelium of the neck of the tube, and of the neighbouring part of the capsule: this epithelium is covered with cilia, which were seen in active motion eight hours after death. *ep''*. Detached epithelial particle, more highly magnified, showing the relative length of the cilia, as they appeared in this specimen. *cav'*. Cavity of the capsule, in which the capillaries, *m*, lie bare, having entered the capsule near *t*, where the view is obscured by another tube. Magnified about 320 diameters.

Fig. 16. *Plan of the renal circulation in Mammalia*. The relative proportions and the character of the several parts are accurately copied from preparations of the *Human* kidney. The artery *a*, (coloured pink) is seen giving a terminal twig *af*, to a Malpighian tuft, *m*, from which emerges the efferent (or portal) vessel *ef* (coloured yellow). Other efferent vessels are seen, *e*, *e*, *e*. All these enter the plexus of capillaries *p* (coloured blue) surrounding the uriniferous tube *t* (coloured red). From this plexus the emulgent vein *e v* springs. Supposed to be magnified about forty diameters.

Fig. 17. *Plan of the renal circulation in animals furnished with a portal vein from an extraneous source*. The colours correspond with those of fig. 16. The relative proportions and position are copied from the kidney of the *Boa* (p. 64), of which a vertical section of one half of a lobe is supposed to be made. *a*. Artery. *af*. Terminal twig going to the Malpighian body. *ef*. Efferent vessel of the Malpighian body emptying itself into a branch of the portal vein *p v* on the surface of the lobe. *b*, *b*. Ultimate branches of the portal vein, entering the capillary plexus *p*, surrounding the uriniferous tube *t*. *u*. Branch of the ureter on the surface of the lobe. *ev*. Emulgent vein within the lobe, receiving the blood from the plexus surrounding the uriniferous tubes. Supposed to be magnified about forty diameters.



a arterial branch.
af afferent vessel of M. body.
b branch of Eff.^{t} ves.^{l} or portal vein.

bm basement membrane.
c capsule of M. body.
cav cavity of tube or ditto
d dilat.^{n} & division of aff.^{t} vessel.

e or ef Eff.^{t} vessel of M. body.
ev emulg.^{t} vein.
m M. tuft.
p plexus of the tubes.

pv portal vein.
t tube.
u ureter.